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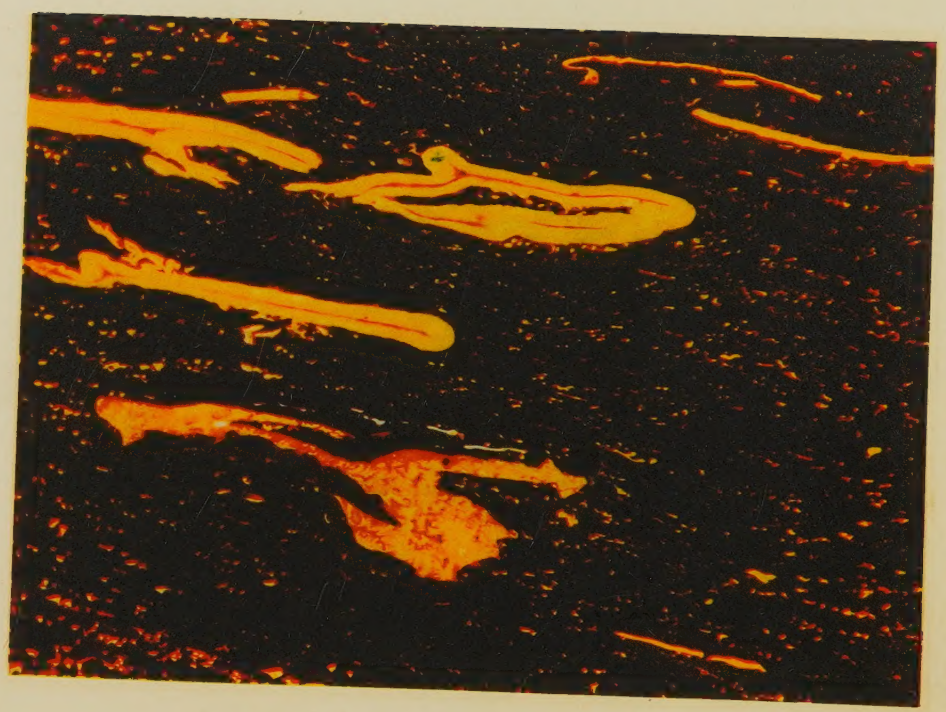

Micro-section of durain showing megaspores and microspores by transmitted light. Natural colours.

(*magnification* 50)

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

FUEL RESEARCH BOARD

TECHNICAL PAPER NO. 11

THE MICROSTRUCTURE OF A COAL SEAM

By J. LOMAX, F.G.S., A.L.S.

LONDON: PUBLISHED UNDER THE AUTHORITY
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PREFATORY NOTE

THE Technical Papers of the Fuel Research Board form a series of special papers and reports on the results of work carried out at H.M. Fuel Research Station or elsewhere. This paper gives the results of one of the investigations carried out at the Lomax Palæo-Botanical Laboratories of the Lancashire and Cheshire Coal Research Association, with assistance from the Department of Scientific and Industrial Research.

A large number of sections of coal from various seams have been prepared by the Lomax Palæo-Botanical Laboratories and subjected to close examination, both visually and by means of photo-micrographs. For the purposes of the Physical and Chemical Survey of the National Coal Resources, reports illustrated by photo-micrographs and by hand-coloured photographs have been drawn up for a number of seams.

The cost of reproduction prohibits the publication of all these reports, but it is thought that the publication of a typical report would be of value to workers on the composition of coal, as well as to geologists and palæo-botanists. The report on the Lanterne Seam of the South Wales Coalfield has been selected as a typical report. Sections similar to those from which the photo-micrographs have been made have been prepared for other coal seams, and a list of these is given at the end of this paper, together with the place where they are deposited. Many examples of single sections, cut to illustrate particular specimens of coal, are deposited in the Geological Museum, Jermyn Street, S.W. 1.

The plates, showing the photo-micrographs of coal sections, have been reproduced by the collotype process, so that they can be examined for detail with a magnifying glass.

Department of Scientific and Industrial Research,
16, Old Queen Street, London, S.W. 1,
March, 1925.

THE MICROSTRUCTURE OF A COAL SEAM

The Lanterne Seam, Llanharan, South Wales

INTRODUCTION BY R. V. WHEELER

WITHIN recent years the study of the structure of coal, as revealed in transparent sections under the microscope, has received attention from an increasing number of investigators both in this country and abroad ; and the publication in the scientific and technical journals of accounts of these investigations has rendered a coal section a " familiar object of the microscope."

It is general knowledge that coal has been formed from plants, and that by suitable treatment the presence in it of well preserved plant structure can still be recognised. The examination of such plant structures while of absorbing interest to the palæo-botanist, is also assuming importance to others engaged in the examination of coal ; and some of the bolder spirits have been tempted to make broad generalisations relating the industrial value of a coal to the predominance in it of a given type of plant structure.

Whatever utility may attach to these attempts to evaluate a coal from its appearance (and there are instances in which the utility has been considerable), the accumulation of accurate observations respecting many varieties of coals cannot fail to add to it. In particular, much interest lies in the intimate examination, layer by layer from floor to roof, of a complete coal-seam ; a laborious undertaking and one requiring expert knowledge on the subtleties and frailties of coal considered as a sliceable material. Foremost amongst the experts in this subject is Mr. James Lomax, to whom scientists throughout the world owe a debt of gratitude for his life-long devotion to his self-chosen study ; there are many who have found indispensable to their researches the magnificent sections which Mr. Lomax knows so well how to prepare.

The Lomax Palæo-botanical Laboratories have made complete microscopical examination, from floor to roof, of a number of coal seams in Great Britain. These are of great value in connection with the Fuel Research Board's Physical and Chemical Survey of the national coal resources, and are receiving careful study. The examination of one seam sample involves the preparation of some hundred photo-micrographs and the publication of all the records is impossible owing to the expense of reproduction. The present report deals with the examination of one seam (The Lanterne Seam of the South Wales Coalfield) and is published as a typical example of the work.

This report contains many beautiful examples of well-preserved plant-structures and should have a high educative value. The

examination of the seam begins at the bottom and the first photographs are of sections (vertical and horizontal*) of the seat-earth ; thereafter, photographs are shown of succeeding sections taken at intervals of about one inch progressing gradually upwards to the roof of the seam. When marked change in the structure of the coal was observed, a special horizontal section was prepared in that region and numbered to correspond with the nearest vertical section. The general scheme of sampling, showing the position of the different sections in relation to the seam as a whole, is illustrated on the key plan (page 14). The approximate positions of the preparations from which the photo-micrographs were taken are also shown.

In the descriptions of the photo-micrographs that follow, it is convenient to consider the vertical and horizontal sections in each region together, and the reader should therefore study the characteristics of each pair of photographs, for example, 1 V (vertical) and 1 H (horizontal), in conjunction with the description. All the micro-photographs are of the same degree of magnification, namely, 20 diameters.

As seen under the microscope, sections of coal appear in colour ranging from light yellow to deep amber or red, dependent in part upon the degree of thinness of the slice, and in part upon the nature of the different ingredients. Spore exines, for example, which are perhaps the most readily recognised plant entities in coal, are almost always of a deeper shade of amber than the ground mass in which they lie, and are often of a distinct red colour. It has not been found possible to reproduce the photographs contained in this report in their natural colours, but as a frontispiece there is given a typical example of a coloured photograph† of a section of coal obtained by the " Raydex " process of colour photography. This affords as good a picture as can be desired of the actual appearance of such sections under the microscope.

* Indicated by H and V after the figure number in the text.

† This photograph is the work of Messrs. W. Guider and F. S. Sinnatt.

DESCRIPTION OF THE PHOTO-MICROGRAPHS

BY JAMES LOMAX

The Lanterne seam belongs to the sub-division of the Coal Measures of South Wales, known as the Lower or Steam-Coal Series, which extends from the No. 2 Rhondda seam down to the top of the Millstone Grit, and includes the principal seams of the coalfield.

In different localities, the seam is variously known as the Lanterne, Pentre and Victoria. Its average thickness is about 2 feet 3 inches.

In appearance the coal is bright and lustrous. It is composed of alternating bands of durain, clarain and vitrain, varying in thickness, especially the vitrain, which frequently occurs as thin irregular streaks and lenticles. Fusain is also present in small lenticles but, rarely in regular laminæ.

BLOCK A. (*The seat earth*)

Fig. 1.

These show the seat earth or floor of the seam. In each, fragments of black carboniferous matter can be detected, embedded in a mass of fine grains of silicious material. In certain portions of the seat earth, fairly well preserved plant tissues are visible, as illustrated in the photo-micrograph 1 H*, which shows a seed *Conostoma oblongum* (Will) belonging to the *Pteridospermeæ*, a class of fern-like plants that bore fructiferous organs resembling seeds.

Fig. 2.

These exhibit the upper part of the seat earth in the neighbourhood of its point of juncture with the coal. The vertical photo-micrograph shows carbonised fragmentary plant tissues, whilst the horizontal shows a fine grained matrix of argillaceous matter.

BLOCK B

Fig. 3.

These illustrate the lowest portion of the coal seam, and in each photograph can be seen bodies, which are probably stems, possessing well-preserved vegetable tissues. The tissues appear to be similar to those of some species of *Cordaites*, a carboniferous genera of *Gymnosperms*. The tissues are so well preserved in some instances as to show the pitted character of the tracheides on close examination. In No. 3 V*, the medullary rays are clearly marked. In the experience of the writer it is unusual to find evidence of such plants so near the floor of the seam of coal.

* H denotes horizontal section, V, vertical section.

Fig. 4.

The coal where these preparations were obtained was soft in nature and the photographs show numerous small, well-pronounced cavities. The coal substance is finely laminated and is composed of small bodies of indeterminate nature embedded in a leaf humus, alternating with layers of microspores and megaspores. No. 4 V shows such laminations, whilst No. 4 H shows a portion of a megaspore.

Fig. 5.

In this region of the coal some of the laminæ are composed of the well-preserved remains of megaspores and microspores, as can be clearly observed in the two photo-micrographs. The megaspores are of a comparatively large size, and are ornamented with a fringe around the equatorial region of the spore. This is well shown at A in the horizontal photo-micrograph, and can also be detected, though with difficulty, in the vertical section.

Fig. 6.

These photographs have been taken from a portion of the section containing thin laminæ of partly petrified plant remains, the cell walls of which are remarkably well preserved. In the horizontal section leaf cuticles can be identified at the point marked A.

Fig. 7.

Both these photographs show megaspores embedded in a matrix of microspores.

Sections 3 to 7 were all obtained from the block of coal marked B on the section of the seam (page 14) and show that, in general, this part of the seam is composed of the fructiferous remains of the *Lycopods*, including *Lepidodendra*, *Sigillaria*, etc., interspersed at intervals with leaf and other laminæ.

BLOCK C

Block C was a thin layer less than two inches in thickness, in which the number of spores is less than in Block B, the chief ingredient being leaf-like laminations, amongst which some megaspores of a smaller size than those found in Block B can be identified.

Fig. 8.

The vertical photograph shows leaf-like laminations containing one or two megaspores. The horizontal photograph was obtained from a preparation cut through one of the leaf laminæ, and in it the cellular tissues of the leaf cuticles can be detected.

The coal in Block C was very fragile and considerable difficulty was experienced in obtaining preparations from it.

BLOCK D

The thickness of the bed of coal in Block D was about six inches, and it was separated from Block C by a thin parting composed of fusain, and from Block E, above it, by a thin band of dirt.

Fig. 9.

The photo-micrographs have been made from a region chiefly composed of laminations of megaspores and microspores. The microspores are particularly well-defined.

Fig. 10.

Photo-micrograph 10 V has been obtained to illustrate a transverse section of a thin lenticle of fusainized wood, the tissues of which can be seen quite plainly. It is probably a portion of the periderm or inner bark of a *Sigillarian* or *Lepidodendroid* stem. It will be observed that short fissures exist at the outer edge of the fusain, and it can be assumed that the coal in such regions would be easily fractured.

The horizontal photograph shows abnormal bodies (which have been termed *Pyritica stellata*) of a stellate shape, each having a series of radiating arms which meet at a central point. Bodies of this shape are numerous in certain parts of the seam ; their origin and the effect they may have upon the coal when it is exposed to the atmosphere is not clearly known, but it appears that they may be a contributing factor in the disintegration of the coal.

Fig. 11.

This region contains well-defined laminæ of microspores alternating with layers composed of leaf cuticles associated with megaspores. The megaspores are clearly visible in the horizontal photograph. From this point upwards in the block of coal the number of megaspores gradually increases, and these portions of the seam may be spoken of as " spore coal."

Fig. 12.

The megaspores are somewhat different in appearance from those found in the lower part of the seam, the majority being ornamented with fine spines, as distinguished from those in the lower parts of the seam, which are ornamented with a fringe.

Fig. 13.

The vertical photograph has been taken from a specially selected portion of the preparation of coal to illustrate a longitudinal section of a stem with reticulated tracheides (A). This may be a partly petrified stem of a medullosian character. The horizontal preparation is taken from near a thin layer of fusain.

Fig. 14.

As previously mentioned, the upper portion of block D ends in a band of dirt. The two photo-micrographs 14 are taken to

mark the position where the changes can be clearly seen. It will be noticed that there are a large number of round and oval bodies present; these resemble in some respects bodies occurring in boghead, cannels and oil shales.

BLOCK E 1

The next block to be dealt with is E, which is from the central part of the seam. This is by far the most valuable portion and its thickness is about 1 ft. 9 in. As it is difficult to deal with such a thickness of coal as this in the description of the photo-micrographs, it has been divided into E 1, 2, 3, 4 and 5. The lower portion of the section of coal is interspersed with joints and is soft in nature, whilst the upper part is much harder and tougher

The portion E 1 contains, on its lower edge, a part of the dirt band mentioned as occurring above block D.

Fig. 15.

These photographs are taken from the zone marked E 1, and in both the vertical and the horizontal photographs bodies similar to those occurring in Fig. 14 are found. From the vertical photograph it would appear that after deposition the bodies became somewhat flattened into an oval shape.

Fig. 16.

The two photo-micrographs have been taken from the upper edge of the dirt band, in order to illustrate the bodies which have been discussed in the previous descriptions. It will be seen now that the bodies here are smaller in size. In the centre of the vertical section is a thin stratum of organic matter, containing well-defined shrinkage cracks; in the horizontal section there are leaf cuticles at the point A. A little higher in the seam the dirt band gradually disappears and is replaced by a thin layer of fusain containing well-defined remains of wood tissues.

Fig. 17. (*Vertical only.*)

Some portion of the layer of fusain can be seen. In the central part is a portion of the axis of a stem, apparently of some species of a palæozoic family of ferns named *Psaronius.* The stem is composed of two well-defined regions, a central portion including the whole of the vascular system and the broad peripheral zone of cortex. The stem is traversed throughout its length by numerous adventitious roots. A portion of the central axis (A) and of the cortex (B) with the tissues containing the root bundles crushed out of shape can be recognised in the photograph.

Fig. 18.

The vertical photograph is of a portion of the outer cortex of the stem shown in Fig. 17 with the flattened rootlet bundles. In the horizontal section are a number of *Pyritica stellata.*

The plant remains described in this portion of the seam are rarely found in preparations of coal, although they are frequently present in petrifactions from the Upper Foot and Lower Mountain Seams, in the Oldham, Littleborough, Bacup and Burnley districts.

Fig. 19.

These photo-micrographs show the uniform character of the coal substance in a band of coal composed chiefly of leaf laminæ associated with layers of microspores and megaspores.

Fig. 20.

These photographs are taken from a portion about 2 inches above those mentioned in Fig. 19 and show that the coal substance at this point is composed of much finer leaf tissues and other plant remains, with a correspondingly smaller number of megaspores and microspores. It will be noticed that there are a large number of thin laminæ consisting chiefly of leaf remains, in which only a few microspores are seen, and occasional megaspores. The horizontal photograph shows the presence of fragmentary plant remains amongst which microspores can be detected.

In summarising the photo-micrographs in Block E 1, it should be mentioned that slightly above the fusain band described in Figs. 17 and 18 a number of vertical joints exist, all radiating from the fusain zone. It would appear from this that the band of fusain has had a disintegrating effect in an upward direction, as few of the joints pass below the fusain band. In placing this observation on record it is suggested that it may have a bearing upon the structure of the coal seam, as the presence of the layers of fusain is of importance.

BLOCK E 2

This block is about 6 inches in thickness. It is brittle in nature and bright in appearance. The preparations show that the material is composed of finely divided humic matter with leaf laminæ and cuticles at intervals. Remains of the *Lycopods* of the nature of microspores and megaspores can be detected. There are some partings or lenticles of fusain and the coal is divided by a number of vertical cracks which permit of its being broken up into cubical pieces.

Fig. 21.

The two photographs exhibit leaf-remains, the vertical section having been obtained from a band containing three or four leaves, probably derived from the *Cordaites*. In the horizontal photograph the cell structure of the leaves is clearly shown.

Fig. 22.

In the vertical photograph leaf laminæ associated with thin-walled megaspores will be found. The spores differ in many respects from those hitherto noticed in the seam ; small fragmentary plant remains are also present. In the horizontal photograph examples of *Pyritica stellata* can be recognised.

Fig. 23.

This zone is composed of leaf laminæ and a few thin-walled megaspores. In the horizontal photograph leaf cuticles are visible.

Fig. 24.

A number of long leaves can be detected, and also fragmentary plant remains which enter largely into the composition of this part of the seam.

From this description of the preparations some impression will have been gathered of the great divergence there is in the composition of the coal substance. A complete change in character from that found in the lower part of the seam has occurred. The absence of remains of the *Lycopods* in this region confers on the coal a certain brightness, and also renders it distinctly fragile.

BLOCK E 3

Figs. 25 *and* 26.

These sections exhibit the laminated character of the coal substance. In the horizontal photograph (fig. 25) a section of a large leaf is shown, cut nearly parallel to its axis, whilst in fig. 26 similar leaves are shown cut obliquely.

Fig. 27.

This section of the seam includes part of a fusain band (A) with clearly defined wood tissues. In the upper portion of the section is a layer of megaspores. It will be noticed that the spores, as regards their size and ornamentation, differ from those in the lower portions of the seam. The ornamentation on the outer walls of the spores in this section are tuberculated; the horizontal photograph shows this structure very clearly. Fragmentary portions of megaspores are also present.

Fig. 28.

In this zone it will be noticed that the constituents of the coal consist of about two-thirds of megaspore and microspore exines; the remainder consists of small oval bodies associated with leaf laminæ. A number of tuberculated megaspores may also be detected amongst the ground mass.

Fig. 29.

The vertical photograph shows that the region consists mainly of megaspores, of which three distinct species are visible. In the horizontal photograph two species can be detected, the upper one having ribbon-like appendages and the lower small spine-like appendages. The photograph completes this section of the coal, which is followed by a thin layer of fusain.

BLOCK E 4

In this zone the coal possesses a schistose character, but otherwise is fairly strong. The constituents differ considerably

from those found in Block E 3. Fewer megaspores and microspores are present, but there is a larger proportion of small twigs, thin laminæ of structureless organic matter and leaf laminæ.

Fig. 30.

The section consists mainly of fine humic matter containing small megaspores, which can be more clearly recognised in the horizontal section.

Fig. 31.

This section is composed of a small twig which is in the centre of the picture. The structure is clearly visible and the remainder of the coal substance is composed of fine humic matter containing megaspores having spine-like appendages. The horizontal photograph contains a large megaspore with smooth exines.

Fig. 32.

In these photographs there is a thin layer of megaspores the walls of which are comparatively large in diameter but thin in section. The centre of the horizontal photograph is occupied by a megaspore in which the size and thinness of the spore-wall can be observed.

Fig. 33.

This section of the coal consists of a thin band of finely laminated matter.

Fig. 34.

These photographs are taken nearly on the upper surface of Block E 4 to show a zone of almost structureless humus. This is best seen in the centre of Fig. 34, and is a good example of the appearance of vitrain under the microscope. The white lines on the print are shrinkage cracks. The horizontal photograph contains portions of two leaf cuticles.

BLOCK E 5

This part of the coal is about 6 inches in thickness. The lower portion is composed of bright coal, which is soft and brittle, and in this respect resembles the coal of Block E 3.

Fig. 35.

(Not reproduced—omitted as being relatively unimportant.)

Fig. 36.

This section shows well defined laminations amongst which small and thin-walled megaspores can be seen. These are of a different species from the megaspores found in the lower part of the coal. Two of the spores will be found in the centre of the horizontal photograph.

Fig. 37.

The sections contain megaspores of a large size. In the vertical section more than one can be seen ; in the horizontal section one large spore is shown.

Fig. 38.

This part of the coal has a peculiar grain and is grey-black in colour. It consists of small fragments of indeterminate character, with occasional attenuated megaspores. The ground mass is studded with minute grains of mineral matter.

Fig. 39.

This horizon of the coal consists largely of megaspores, although leaf laminæ can be detected.

Fig. 40.

This part of the coal constitutes the "spore coal." Megaspores appear in a matrix of microspores. This band is only about an inch thick, after which the spores rapidly decrease in number and are replaced by regularly laminated leaf humus.

BLOCK F

This band of coal is about $2\frac{1}{2}$ inches in thickness and is bright in appearance ; it is soft, friable and tends to break into small cubical pieces.

Fig. 41.

This section is composed of leaf-like laminations with occasional narrow bands of durain and vitrain. In the horizontal section a whole mass of broken distorted leaves can be identified, and the whole of the thickness of this section is composed of similar constituents. Remains of the *Lycopods* are almost absent, whereas at the upper part of Block E 5 there was a whole mass of these remains. Block F is composed of coal which has been formed from entirely different plant remains than those that formed E 3 to 5.

BLOCK G

This block is about $3\frac{1}{2}$ inches in thickness. Outwardly it is similar to Block F in appearance, but as we pass upwards the spore-content increases until in the middle of the block there are a considerable number of microspores and megaspores.

Fig. 42.

This section shows a band of coal containing vitrain and clarain, the latter being in the centre part of the vertical photograph. In the horizontal photograph two large megaspores are shown.

Fig. 43.

This section is of coal composed of leaf laminations alternating with bands of microspores. In the horizontal photograph a section of a leaf of *Cordaites* can be seen. Four of the vascular

strands and the intermediate soft cellular tissues of the leaf can be recognised in the photograph. Part of the leaf is fusainized and part is petrified. In the remainder of the photograph the leaf tissues are shown to have been crushed and the structure of the constituents is almost obliterated.

Fig. 44.

The upper and lower portions of the vertical photograph show clarain, the constituents of which are megaspores, microspores and leaf laminæ. In the horizontal photograph megaspores characteristic of the upper part of the seam are shown. These are large in size and ornamented with an irregular fringe. In some respects these megaspores are similar to those found in the bottom of the seam, Block B. The resemblance is not complete, however, and it must be remembered that a very great length of time has probably elapsed between the deposition of the coal in Block B and of that in Block G.

Fig. 45. (Not reproduced.)

These are composed of small twigs and humic matter similar to those found in sections 42 and 44.

BLOCK H

This band of material is a dirt band and is about 2 inches in thickness. It is similar in many respects to the coal at the bottom of E 1 illustrated in photographs 14, 15 and 16.

Fig. 46 (*vertical only*), 47 *and* 48.

These photographs should be compared with 14, 15 and 16, to which they are similar.

BLOCK I

Directly above the dirt band H is another thin bed of coal about $1\frac{1}{2}$ inches in thickness.

Fig. 49.

These photographs show the general character of the coal which is that of most humic coals.

Fig. 50.

These photographs are taken at the junction of the seam with the roof shales. The material is composed of finely laminated leaf humus in which fragmentary plant remains can be detected.

By the courtesy of the Authorities at the Universities, Collieries and Museums severally concerned, the Department of Scientific and Industrial Research are able to publish the following list of the seams of which thin sections have been prepared and the places where the latter are deposited :—

Name of seam.	Name of Colliery and/or locality from which sample was obtained.	Place where transparent sections of coal may be seen.
Arley	Exors. of John Hargreaves, Ltd., Bank Hall Colliery, Burnley.	*Lancashire and Cheshire Coal Research Association, Bolton.
Arley	J. & R. Stone, Ltd., The Park Collieries, Garswood, near Wigan.	Department of Scientific and Industrial Research.
Arley	Abram Coal Co., Ltd., Abram Collieries, Bickershaw, near Wigan.	Wigan and District Mining and Technical College, Wigan.
Banbury Seven-Feet.	Birchenwood Colliery Co., Ltd., Birchenwood Colliery, Kidsgrove, Stoke-on-Trent.	*Lancashire & Cheshire Coal Research Association, Bolton.
Barnsley	Ackton Hall Colliery Co., Ackton Hall Colliery, Featherstone, near Pontefract.	University of Leeds (Geological Department).
Barnsley	Barber, Walker & Co., Ltd., Bentley Colliery, near Doncaster.	Ditto.
Barnsley	Hickleton Main Colliery Co., Ltd., Hickleton Main Colliery, Thurnscoe, near Rotherham.	Ditto.
Barnsley	Pickburn, near Doncaster.	Ditto.
Bickershaw Six-Feet.	Abram Coal Co., Ltd., Abram Collieries, Bickershaw, near Wigan.	Wigan and District Mining and Technical College, Wigan.
Cockshead ..	Mossfield Colliery, Ltd., Mossfield Colliery, Longton, Staffs.	Central School of Science and Technology, Stoke-on-Trent.
Four-Feet	Fletcher, Burrows & Co., Ltd., Chanters Colliery, Atherton, near Manchester.	Atherton Collieries, Atherton, near Manchester.
Hard Mine ..	Mossfield Colliery, Ltd., Mossfield Colliery, Longton, Staffs.	Central School of Science & Technology, Stoke-on-Trent.
Lanterne .. .	Llanharan, Glamorgan ..	South Wales and Monmouthshire School of Mines, Treforest.
Mountain, Lower ..	Bispham Hall Colliery Co., Bispham Hall Colliery, Orrell near Wigan.	*Lancashire & Cheshire Coal Research Association, Bolton.

* Lomax Palæo-botanical Laboratories, Lancashire & Cheshire Coal Research Association, Bolton.

Name of seam.	Name of Colliery and/or locality from which sample was obtained.	Place where transparent sections of coal may be seen.
Mountain, Lower ..	Garswood Hall Collieries Co., Ltd., Garswood Hall Collieries, Bryn, near Wigan.	*Lancashire & Cheshire Coal Research Association, Bolton.
Mountain, Middle..	Bispham Hall Colliery Co., Bispham Hall Colliery, Orrell, near Wigan.	Ditto.
Mountain, Upper ..	Bispham Hall Colliery Co., Bispham Hall Colliery, Orrell, near Wigan.	Ditto.
Nine-Feet	Tylorstown, Glamorgan	South Wales and Monmouthshire School of Mines, Treforest.
Ravine or Plodder	Garswood Hall Collieries, Co., Ltd., Garswood Hall Collieries, Bryn, near Wigan.	*Lancashire & Cheshire Coal Research Association, Bolton.
Ravine	Abram Coal Co., Ltd., Abram Collieries, Bickershaw, near Wigan.	Department of Scientific and Industrial Research.
Roger	Ashton-under-Lyne, near Manchester.	Manchester Museum, The University, Manchester.
Shallow	Brereton Collieries, Ltd., Brereton Collieries, Rugeley, Staffs.	The University, Birmingham, and the National Museum of Wales, Cardiff.
Shallow	Walsall Wood Colliery Co., Ltd., Walsall Wood Colliery, near Walsall.	The University, Birmingham.
Sir John Delf ..	Downhall Green, near Wigan.	*Lancashire and Cheshire Coal Research Association, Bolton.
Smith or Three-quarters.	Westhoughton Coal and Cannel Co., Ltd., Westhoughton Colliery, near Bolton.	The Colliery.
Trencherbone ..	S. Scowcroft & Sons, Ltd., Bradshaw Hall Colliery, Darcy Lever, near Bolton.	Chadwick Museum, Bolton.
Wigan Four-Feet & Hoo Cannel.	Abram Coal Co., Ltd., Abram Collieries, Bickershaw, near Wigan.	Wigan & District Mining and Technical College, Wigan.

* Lomax Palæo-botanical Laboratories, Lancashire & Cheshire Coal Research Association, Bolton.

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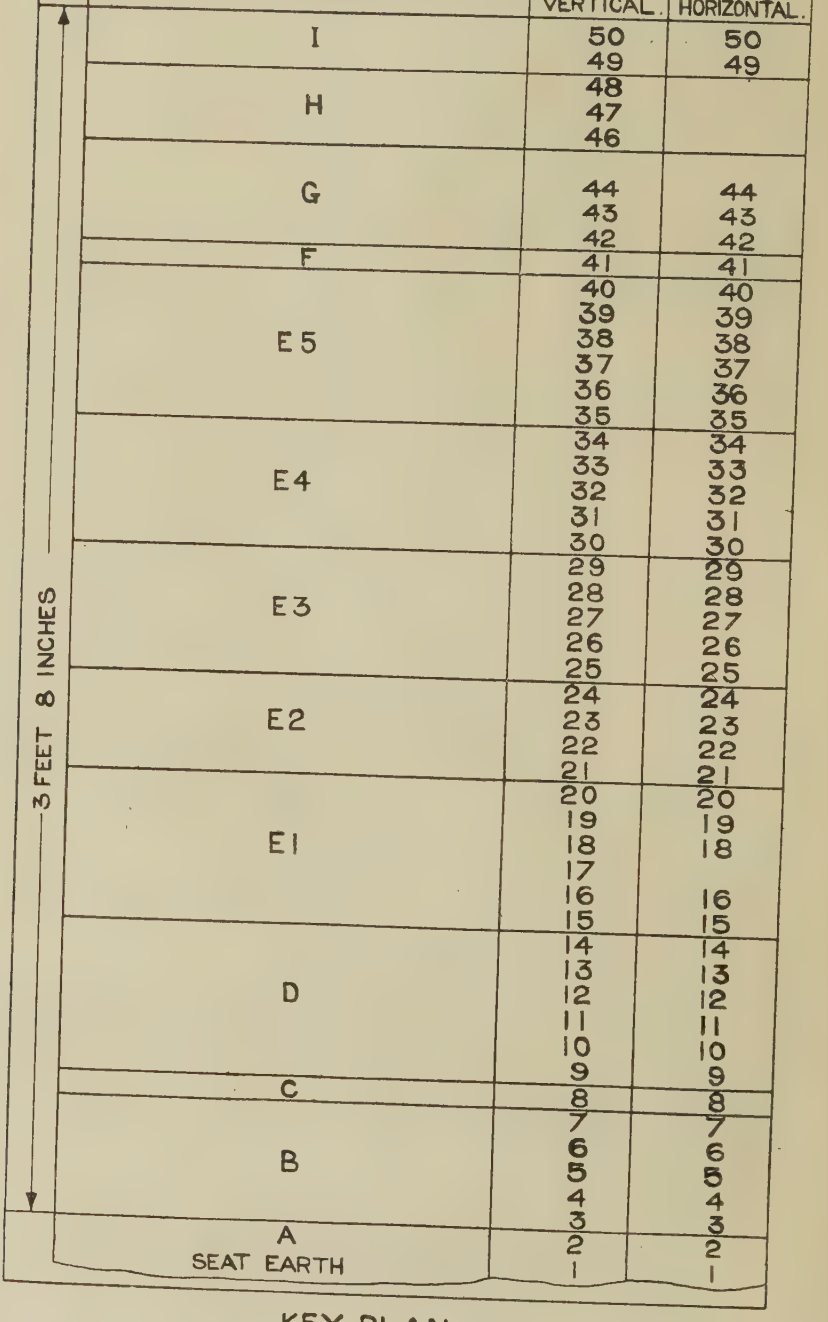
LANTERNE SEAM.

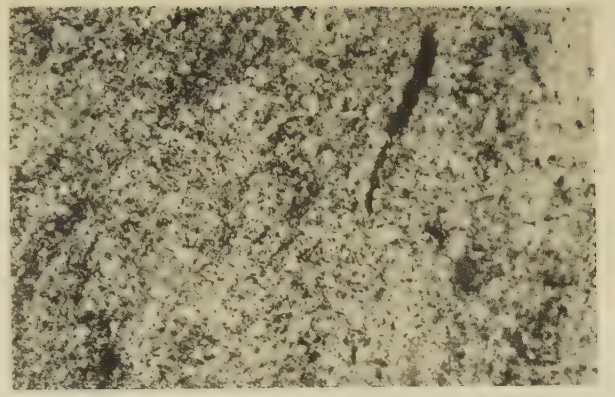
DIAGRAMMATIC SECTION OF SEAM.



DESIGNATION OF BLOCKS OF COAL	No. OF FIG. VERTICAL.	No. OF FIG. HORIZONTAL.
I	50 49	50 49
H	48 47 46	
G	44 43 42	44 43 42
F	41	41
E 5	40 39 38 37 36 35	40 39 38 37 36 35
E 4	34 33 32 31 30	34 33 32 31 30
E 3	29 28 27 26 25	29 28 27 26 25
E 2	24 23 22 21	24 23 22 21
E 1	20 19 18 17 16 15	20 19 18 16 15
D	14 13 12 11 10 9	14 13 12 11 10 9
C	8	8
B	7 6 5 4 3	7 6 5 4 3
A SEAT EARTH	2 1	2 1

KEY PLAN

VERTICAL



HORIZONTAL

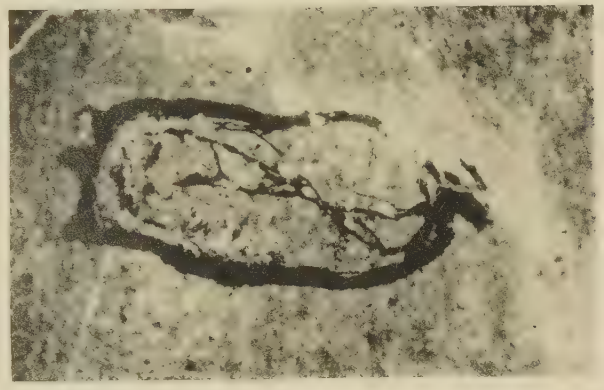
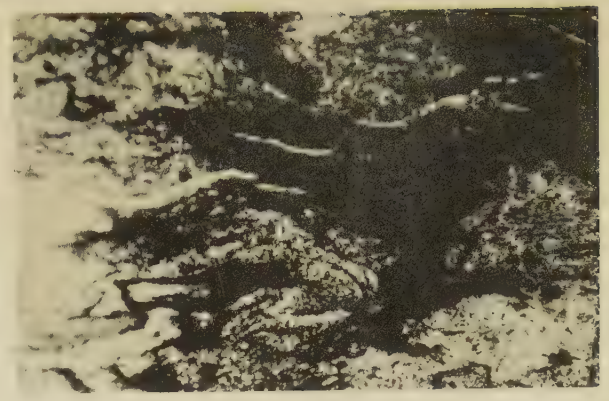


Fig. 1

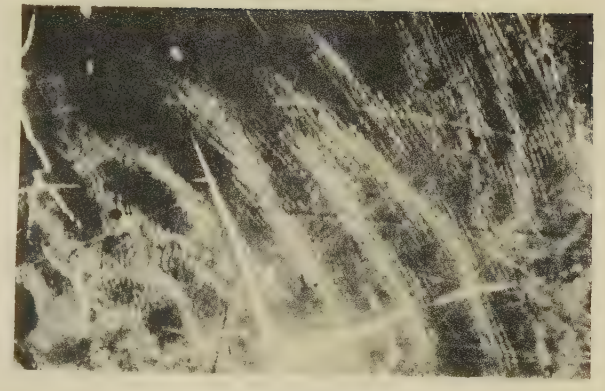
VERTICAL



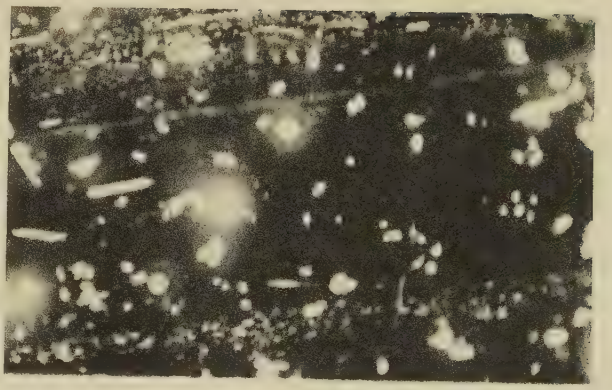
HORIZONTAL

Fig. 2

HORIZONTAL



VERTICAL



VERTICAL

Fig. 3

HORIZONTAL

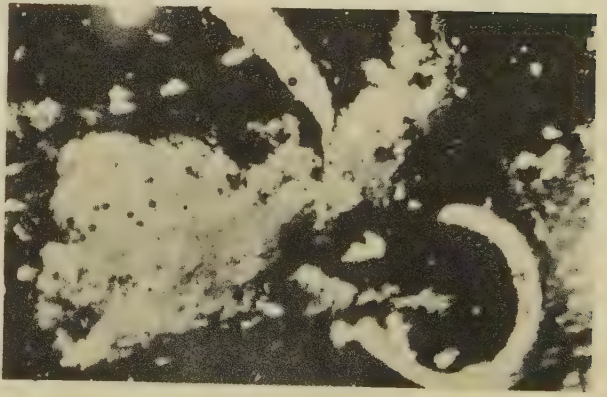
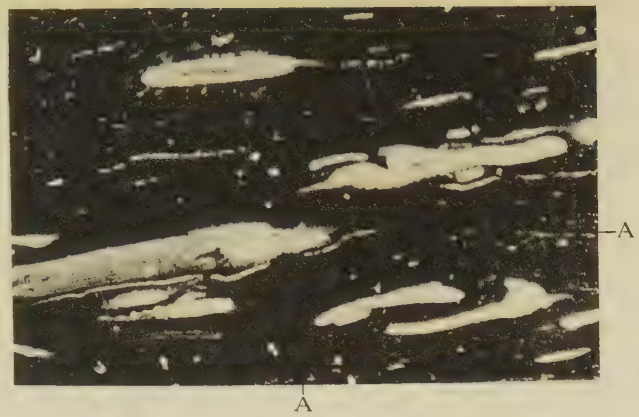
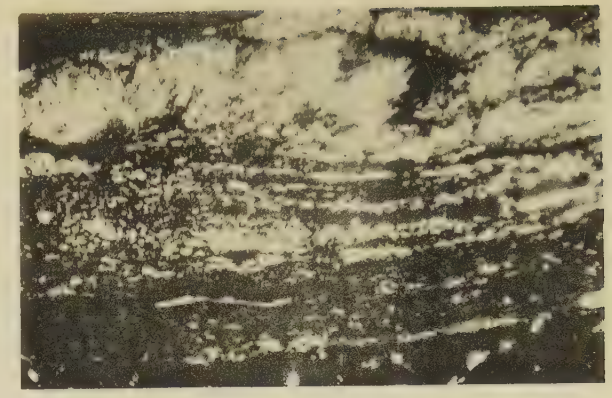


Fig. 4

VERTICAL



VERTICAL



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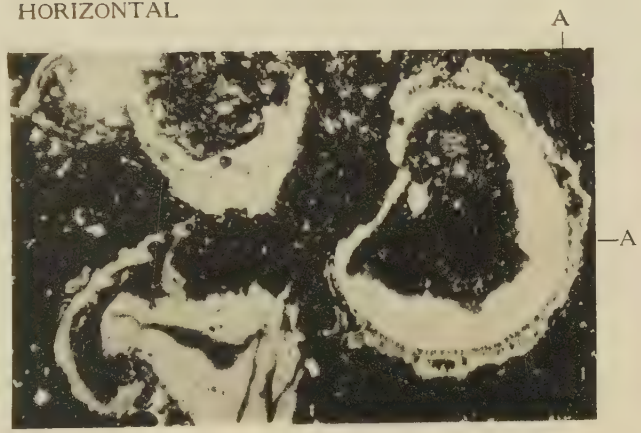


Fig 5

HORIZONTAL

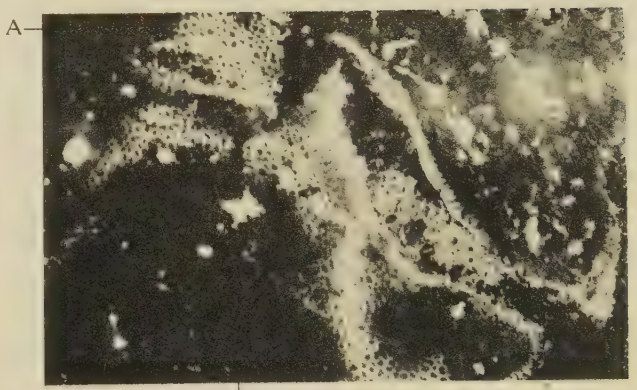
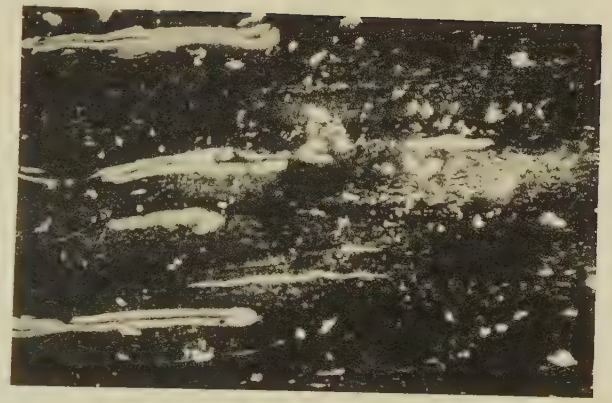


Fig. 6

VERTICAL



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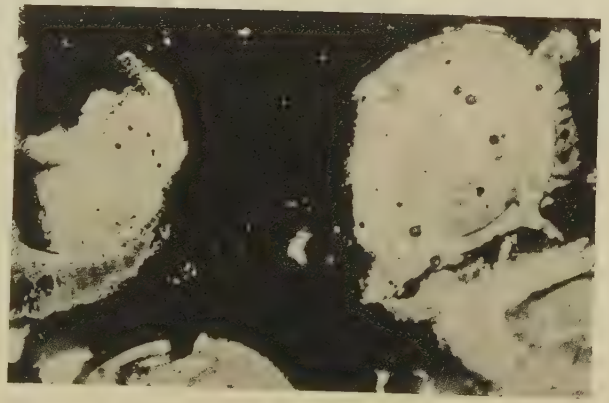
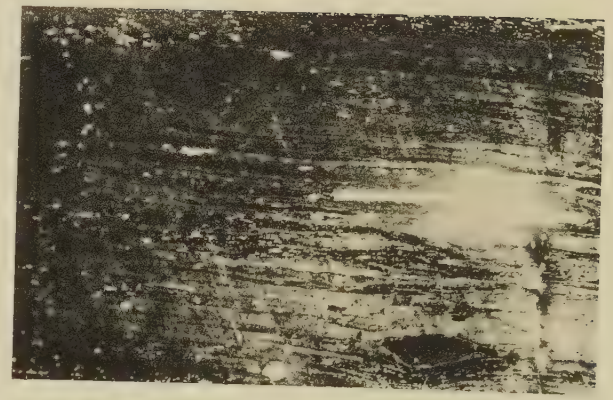


Fig. 7

VERTICAL



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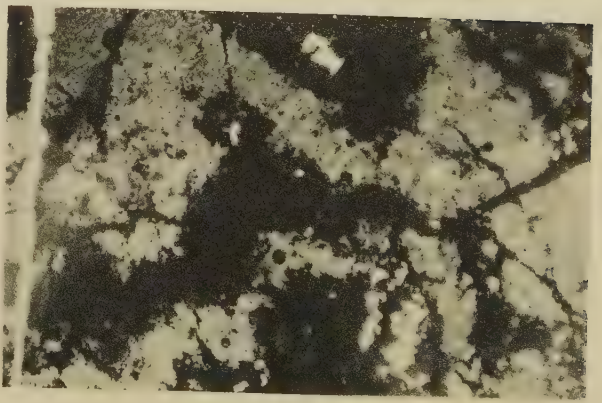


Fig. 8

VERTICAL

HORIZONTAL

Fig. 9

VERTICAL

HORIZONTAL

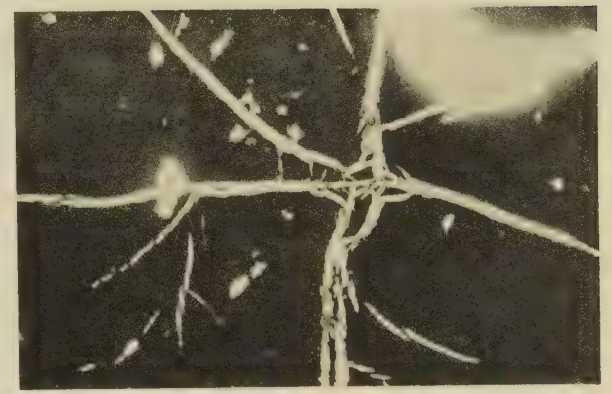


Fig 10

VERTICAL

HORIZONTAL

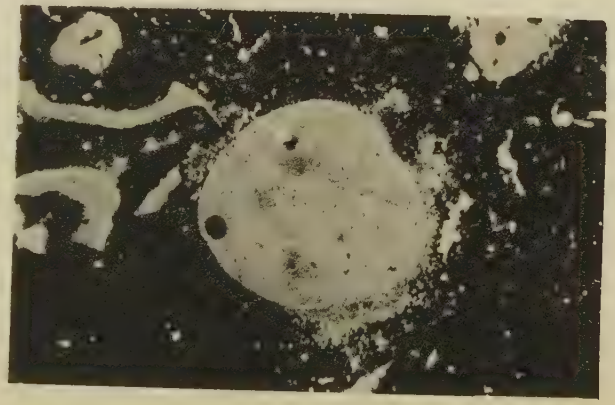


Fig. 11

VERTICAL

HORIZONTAL

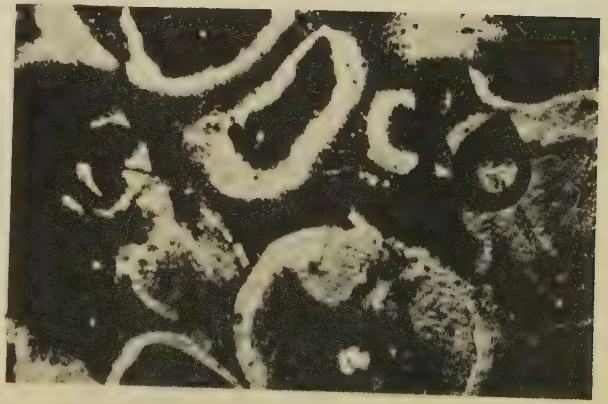


Fig. 12

VERTICAL

HORIZONTAL

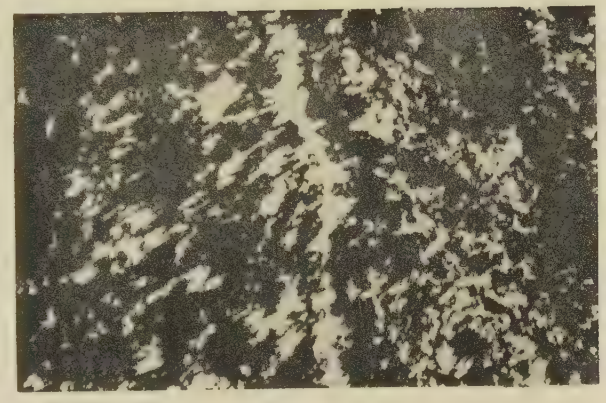
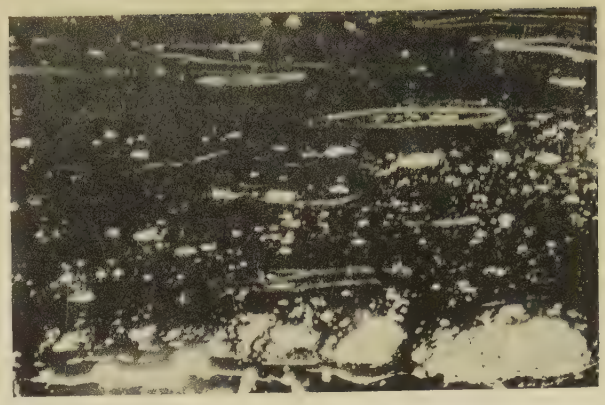


Fig. 13

VERTICAL



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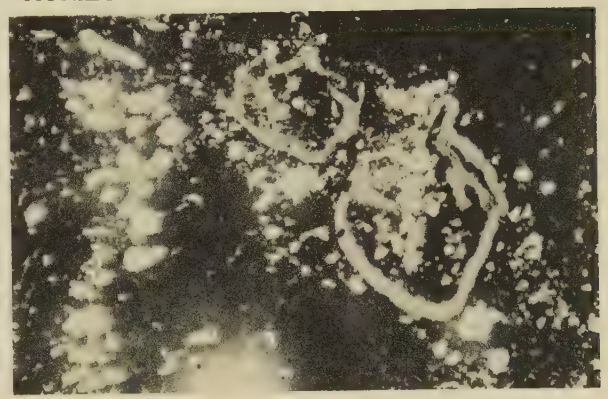
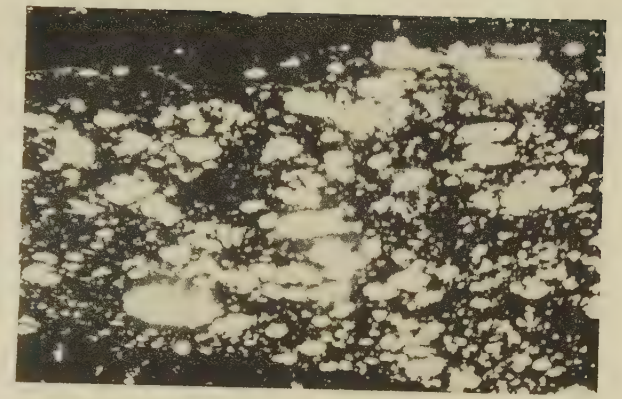


Fig. 14

VERTICAL



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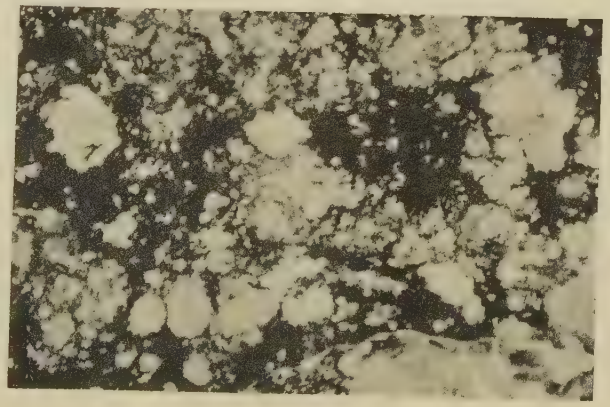
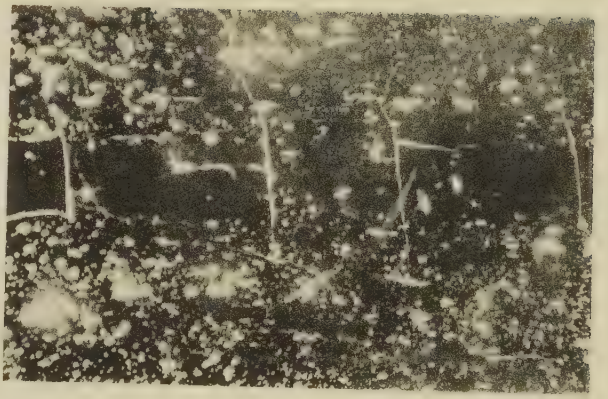


Fig. 15

VERTICAL



HORIZONTAL

A

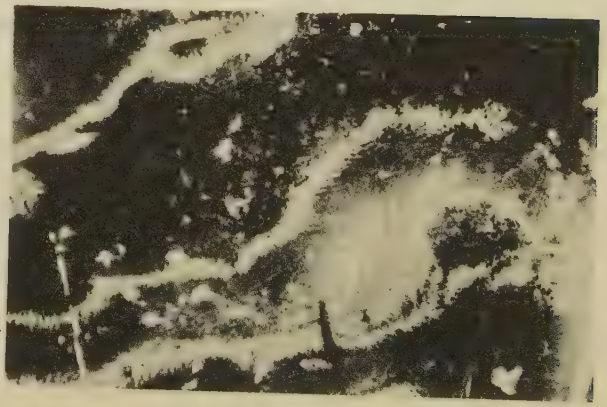


Fig. 16

VERTICAL

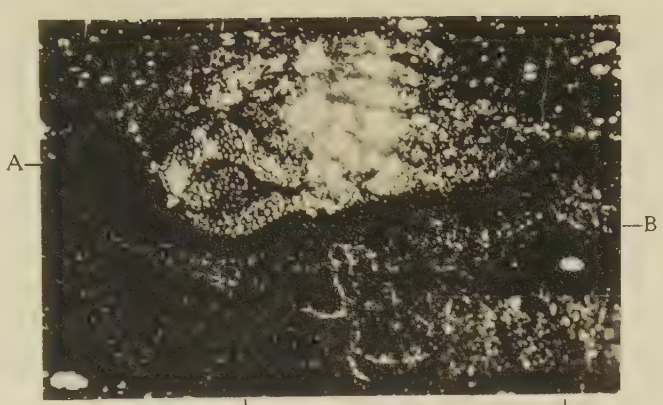
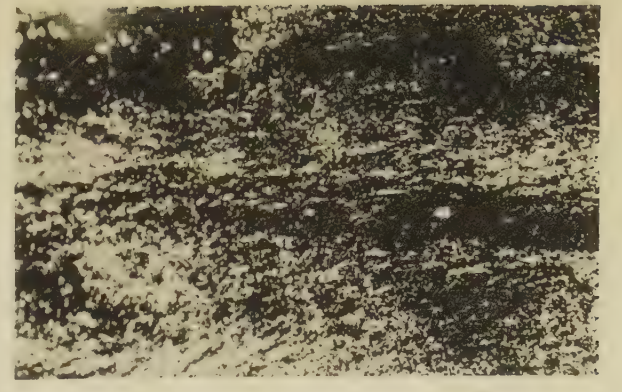


Fig. 17

VERTICAL



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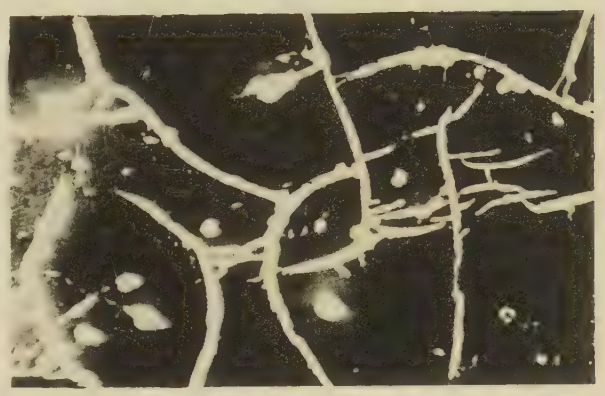
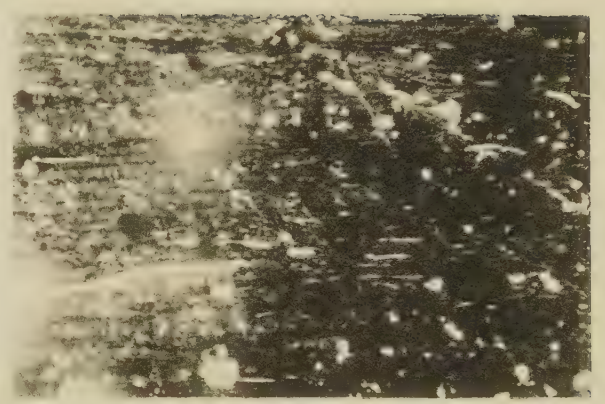


Fig. 18

VERTICAL

VERTICAL



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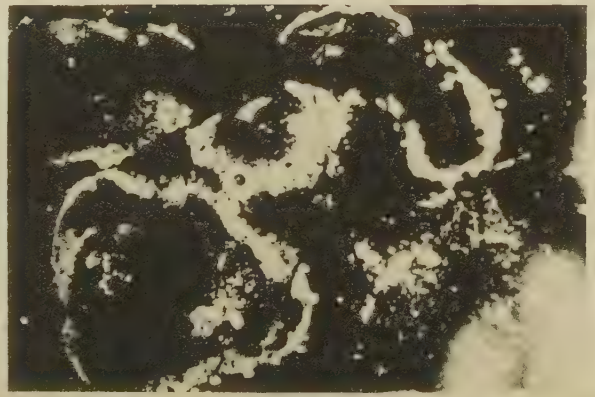

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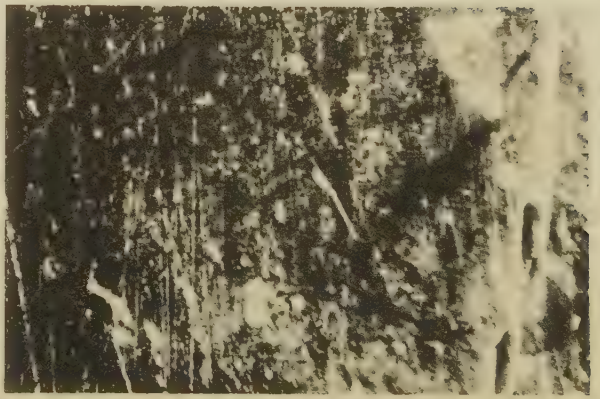

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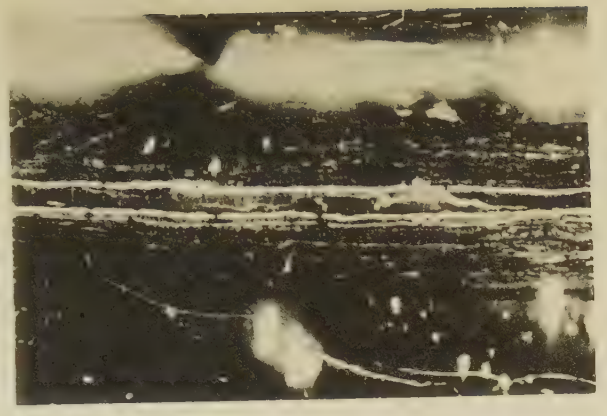

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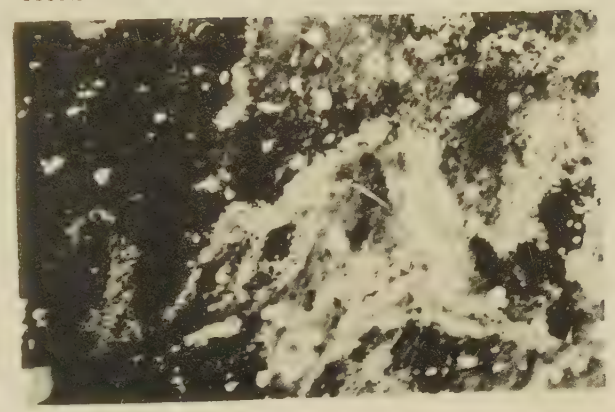
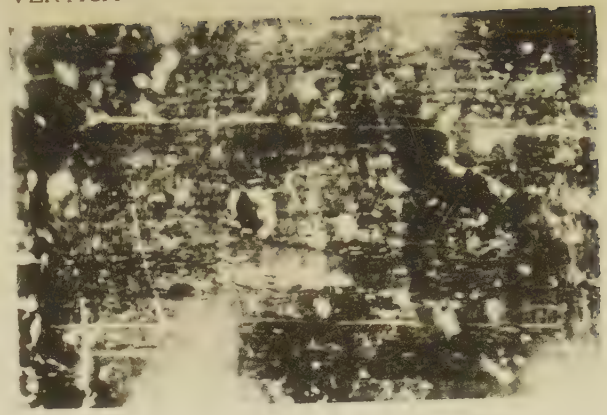


Fig 21

VERTICAL



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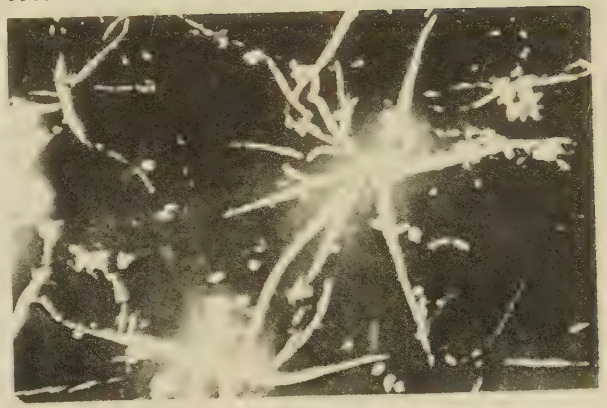
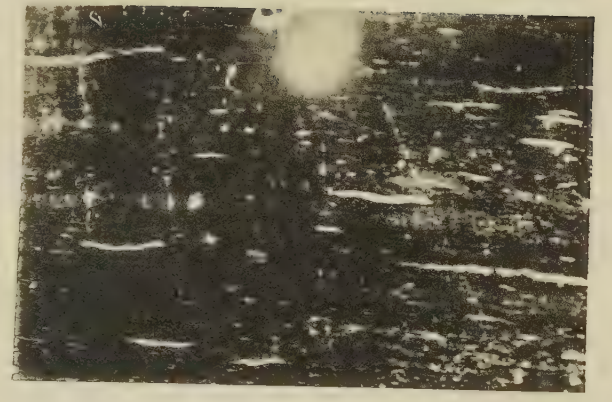


Fig. 22

VERTICAL



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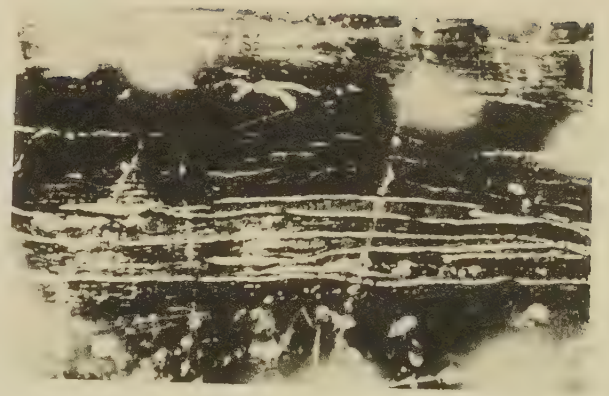

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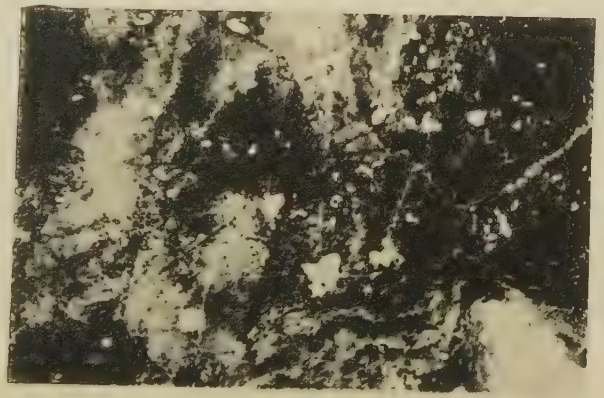


Fig. 23

HORIZONTAL

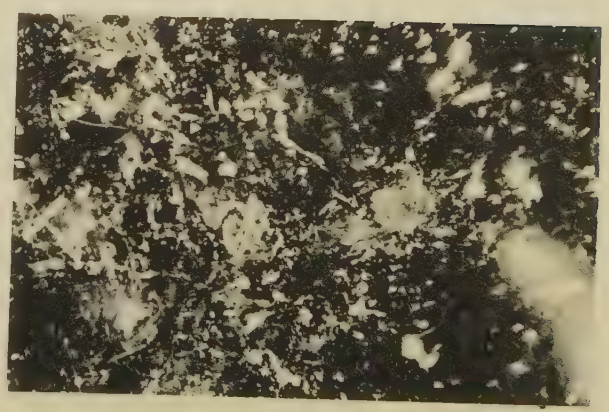
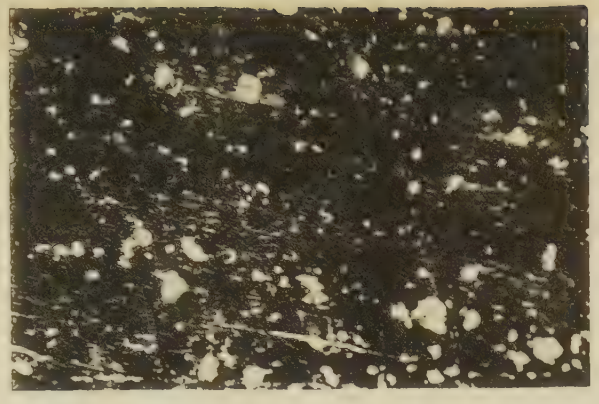


Fig 24

VERTICAL



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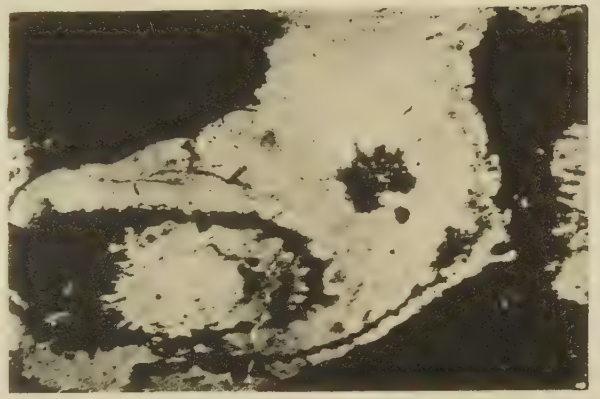
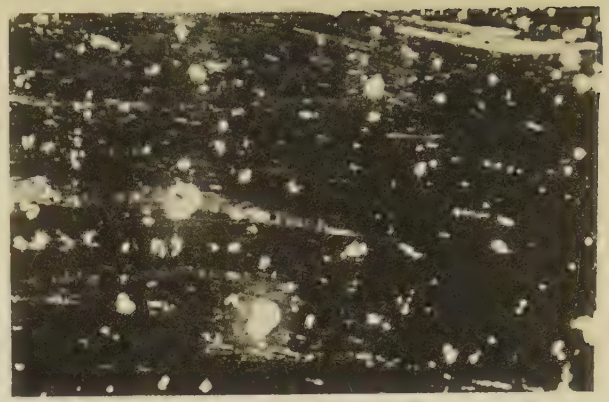


Fig. 25

VERTICAL



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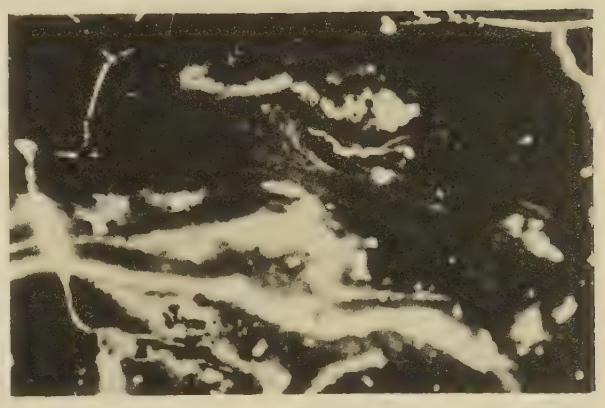
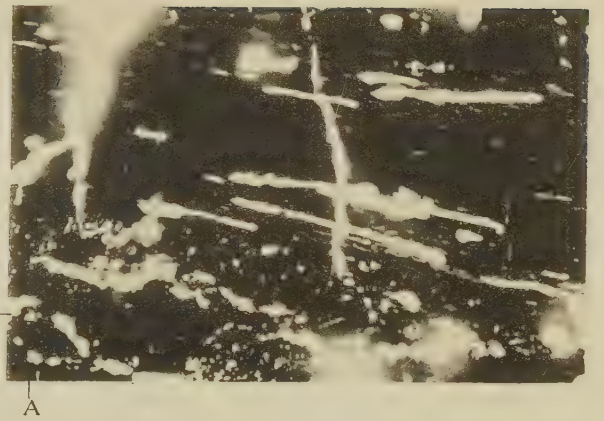


Fig 26

VERTICAL



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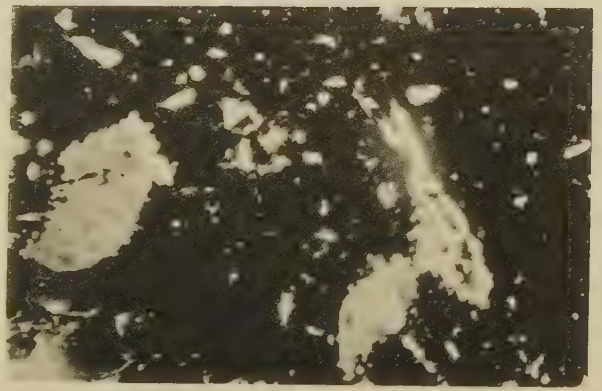
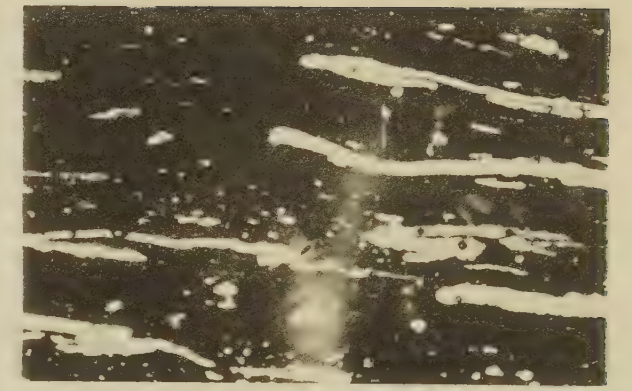


Fig. 27

VERTICAL



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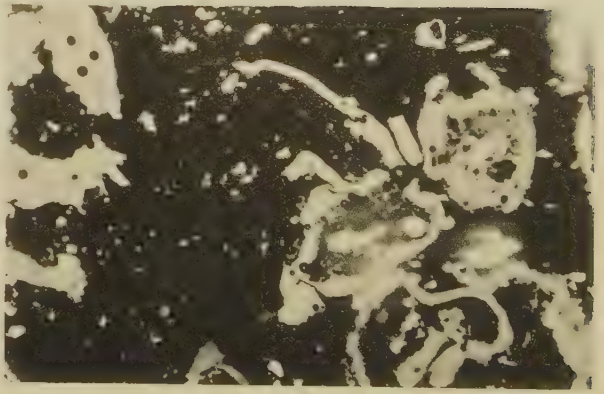
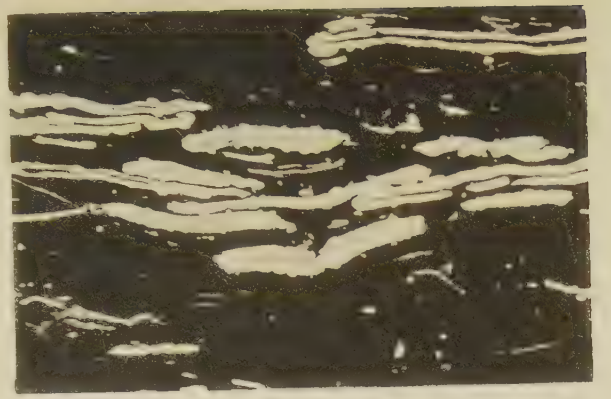


Fig. 28

VERTICAL



HORIZONTAL

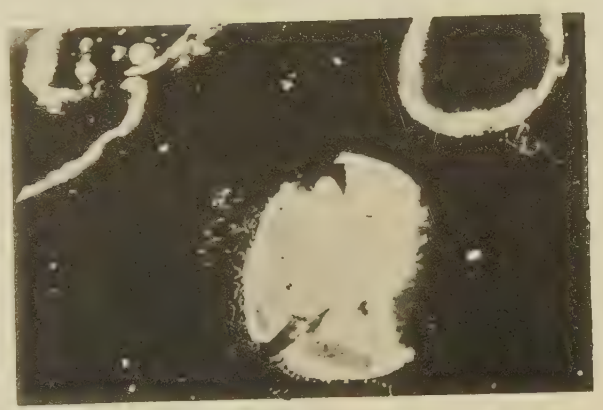
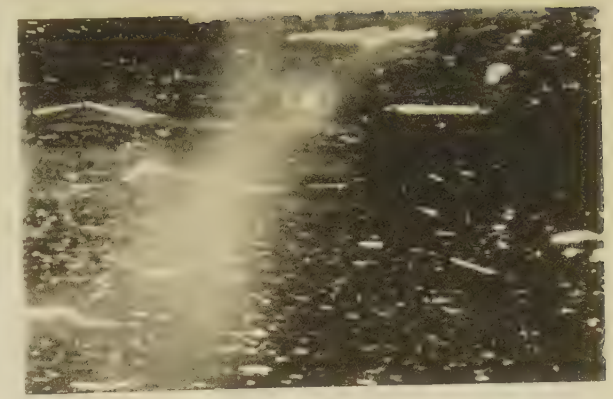


Fig. 29

VERTICAL



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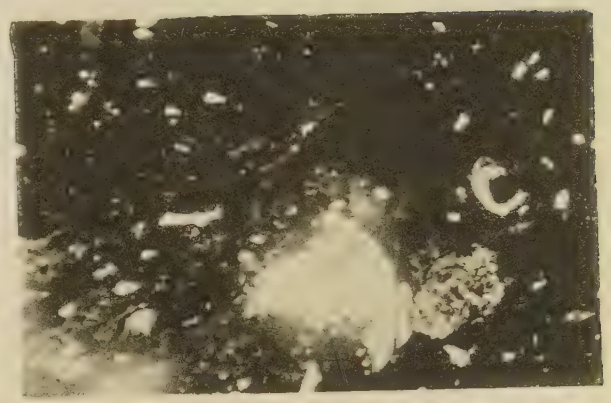
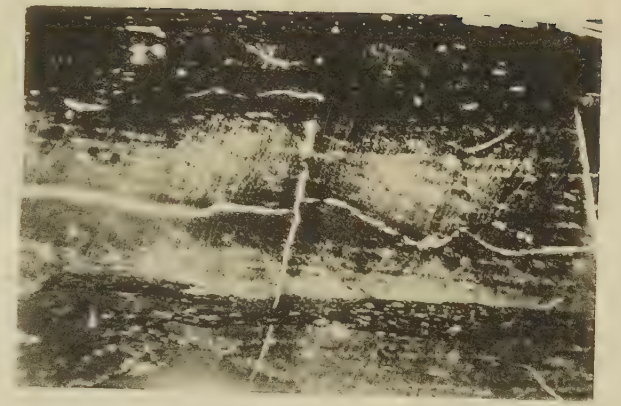


Fig. 30

VERTICAL



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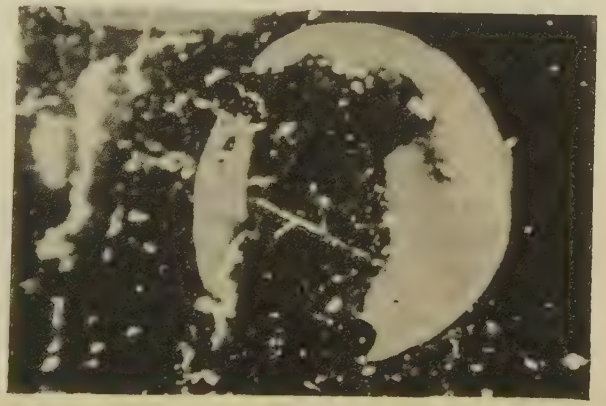
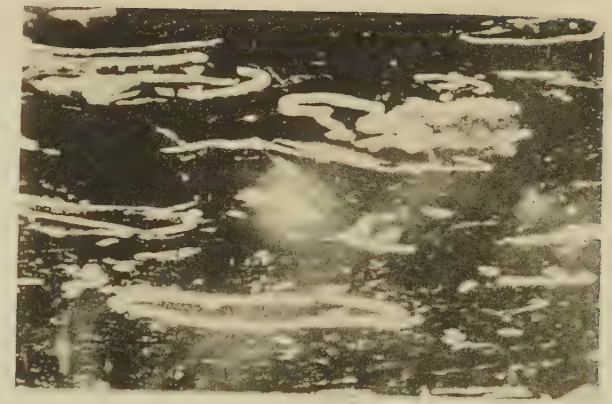


Fig. 31

VERTICAL



HORIZONTAL

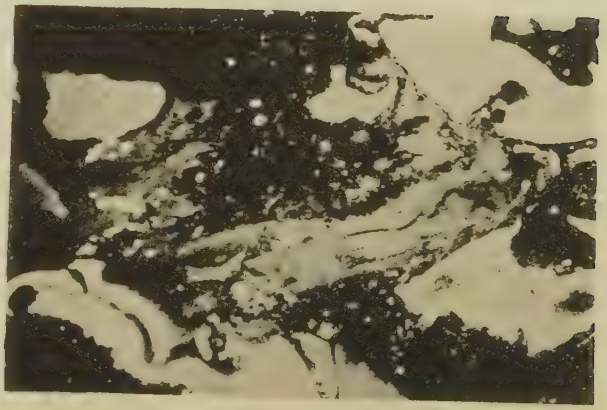
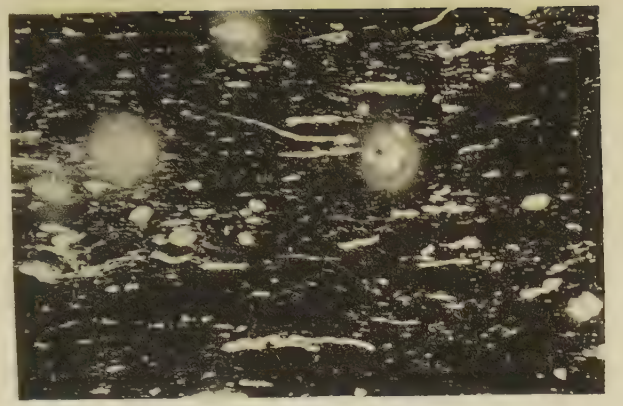


Fig. 32

VERTICAL



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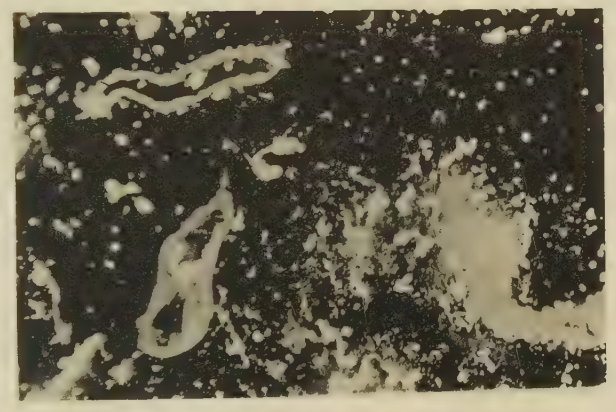


Fig. 33

VERTICAL

HORIZONTAL

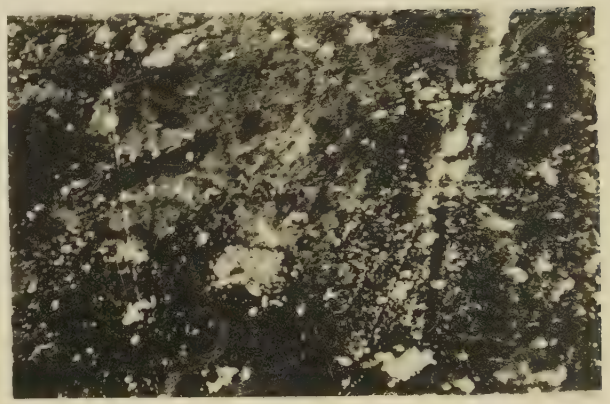


Fig. 34

VERTICAL

HORIZONTAL

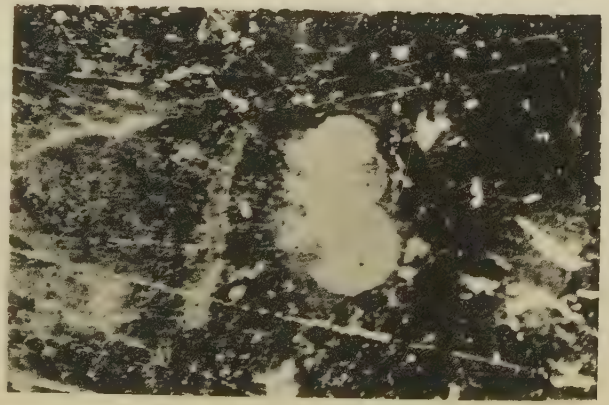


Fig. 36

VERTICAL

HORIZONTAL

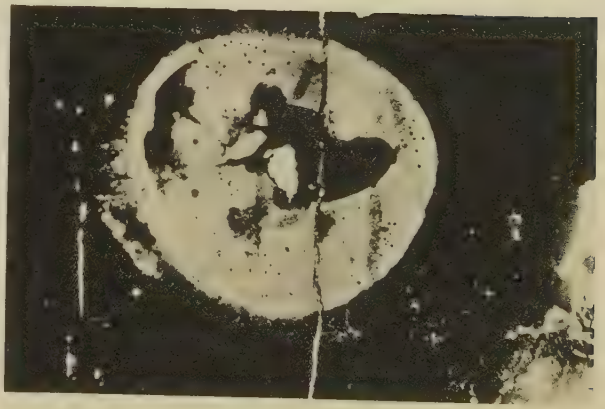
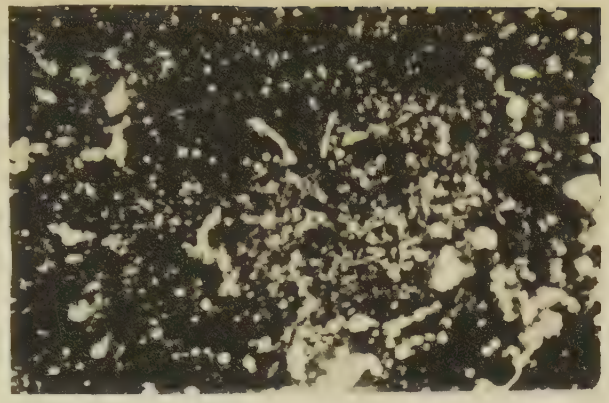


Fig. 37

HORIZONTAL



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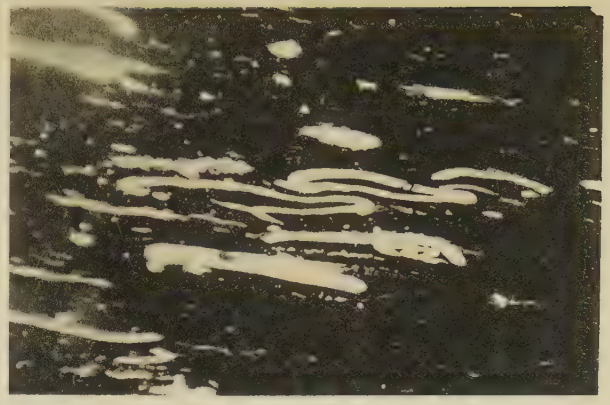

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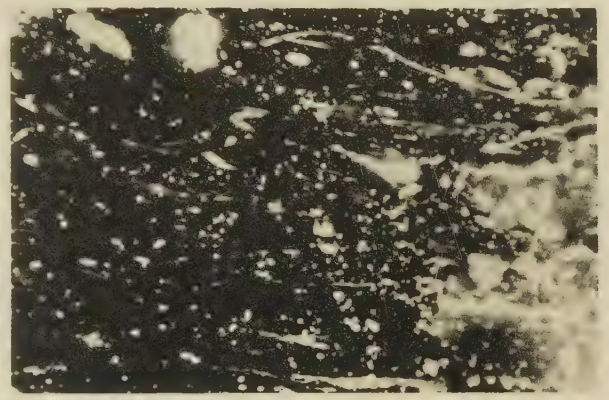


Fig 38

HORIZONTAL

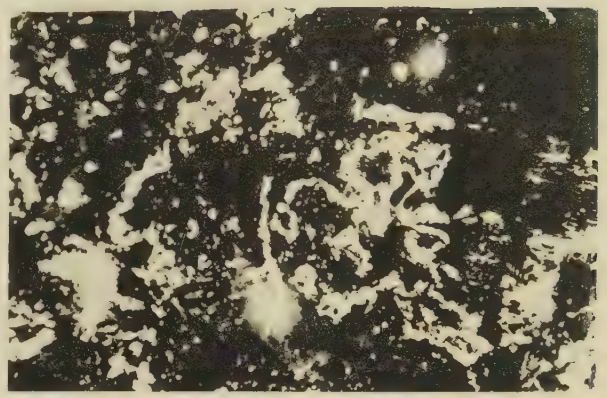
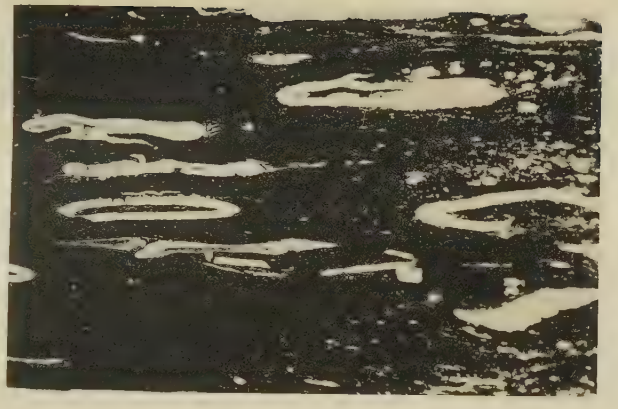


Fig. 39

VERTICAL



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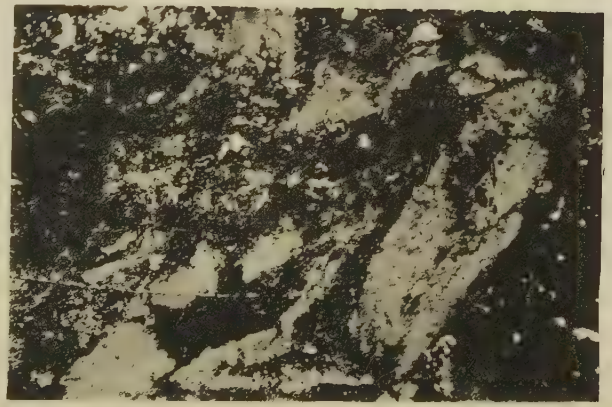


Fig. 40

VERTICAL

HORIZONTAL

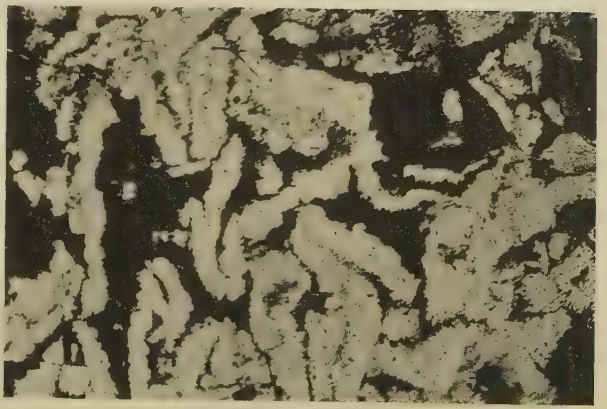
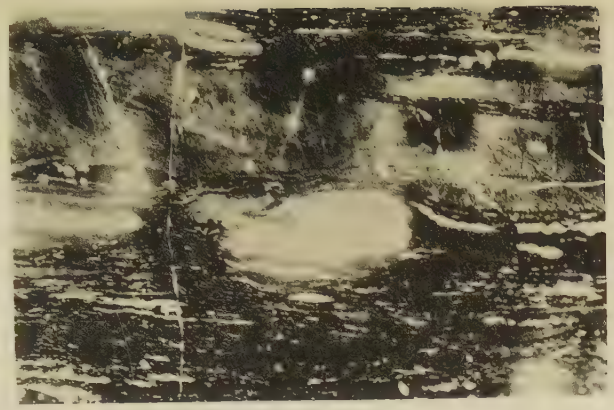


Fig. 41

VERTICAL



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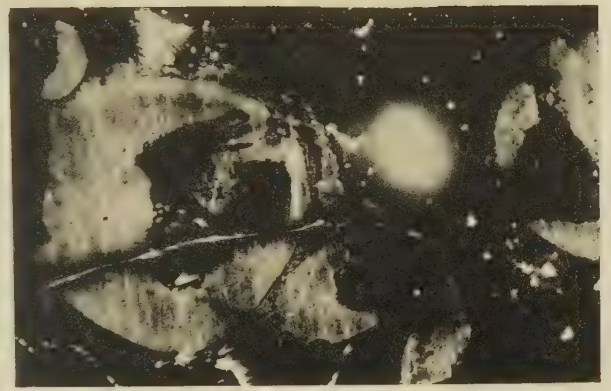
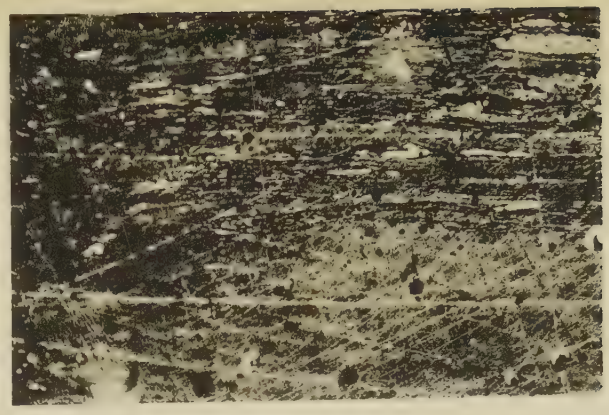


Fig. 42

VERTICAL



HORIZONTAL

Fig 43

VERTICAL

VERTICAL

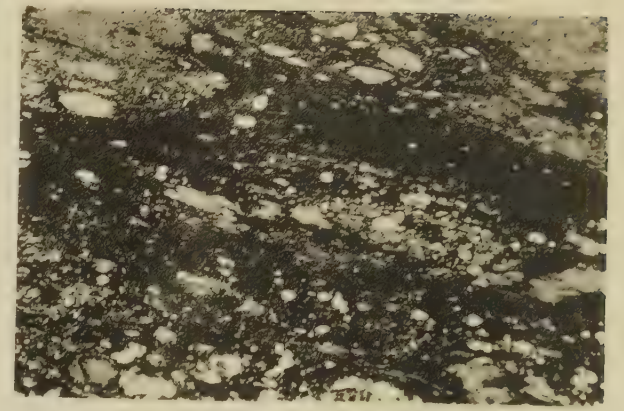


Fig. 46

HORIZONTAL

Fig. 44

VERTICAL

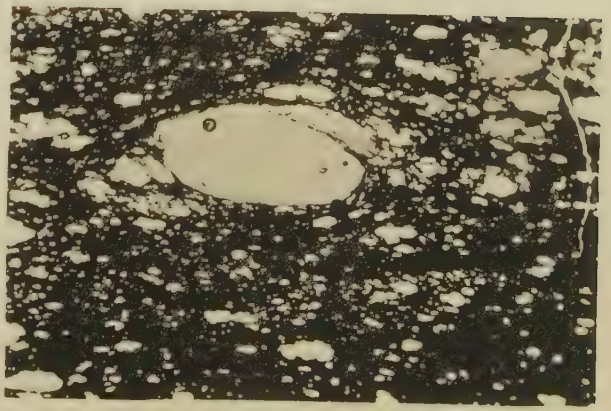
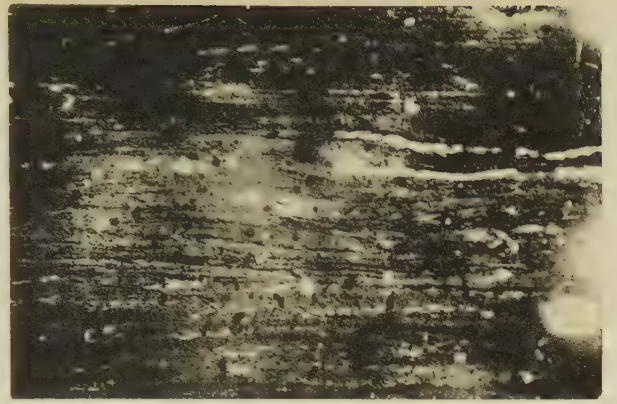


Fig. 47

VERTICAL



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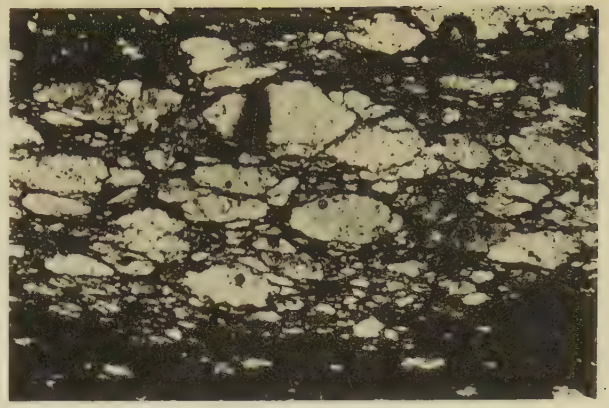

Fig. 48

HORIZONTAL

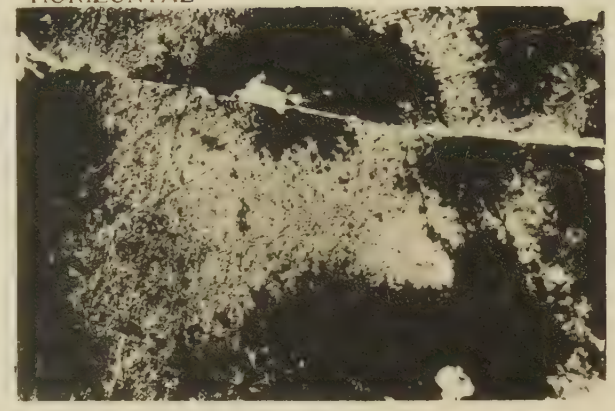

Fig 49

VERTICAL

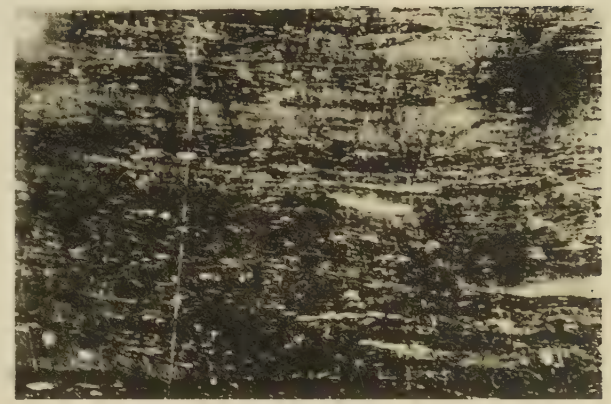

Fig. 50

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